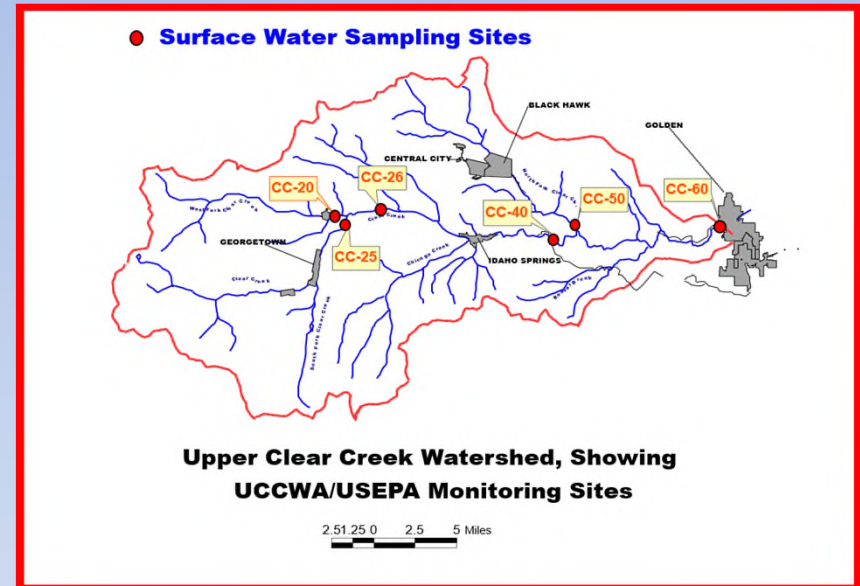
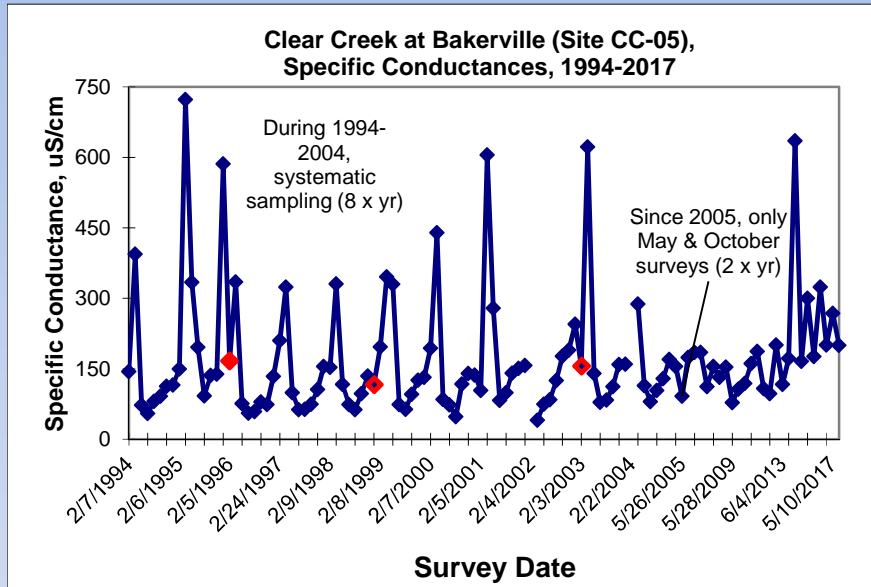


# Benefits of Comprehensive Water-Quality and Hydrologic Monitoring for Upper Clear Creek Watershed Management

*National Water Quality Monitoring Council (NWQMC), 11<sup>th</sup> National Monitoring Conference,  
Denver, Colorado, March 25-29, 2019*



*Presented By  
Timothy D. Steele, Ph.D., TDS Consulting, and  
J. David Holm, Clear Creek Watershed Foundation, Denver, Colorado*

[TDSConsult@aol.com](mailto:TDSConsult@aol.com) & [jdavidholm@gmail.com](mailto:jdavidholm@gmail.com)

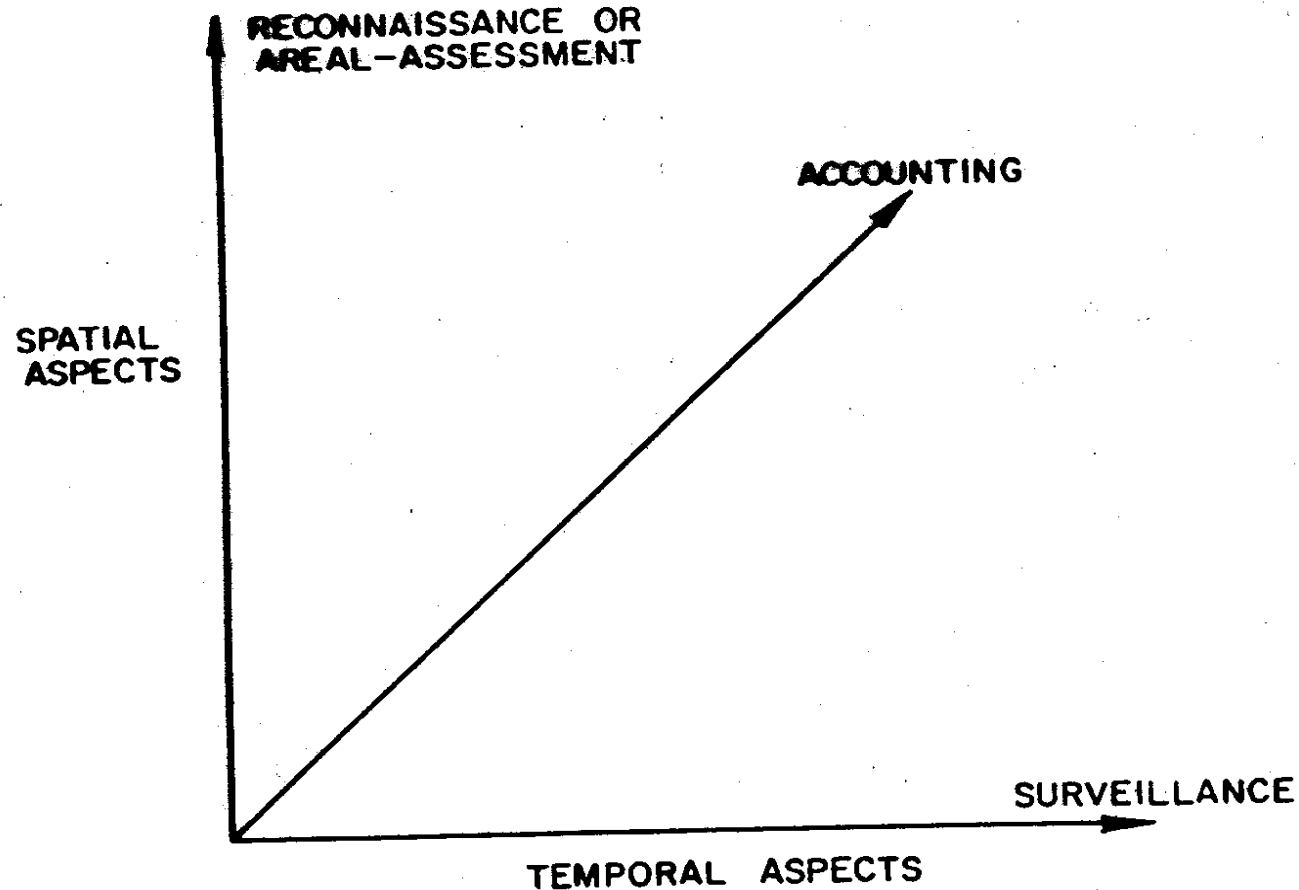
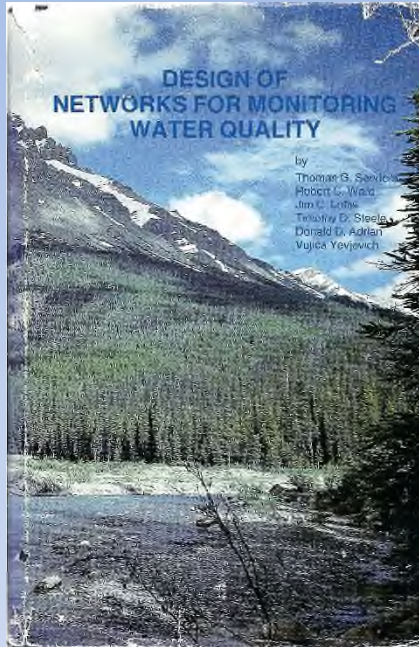


# 1994-2018 UCC Monitoring-Program Highlights

- Watershed Agreement included development and implementation of a watershed-wide “systematic” WQ & TMs monitoring programs.
- Water-quality data span a 25-year period of record; numerous monitoring sites are located at streamflow gaging stations. \*SLCs\*
- Trace-metals (TMs) data are available through the 8/16/18 sampling survey by USEPA-ESAT. Recent sampling-survey results are pending, and continuation of the program is assured through 9/19.
- TMs data have been extracted from the USEPA SCRIBE system and have been transcribed into the CDPHE-WQCD template. \*CDSN\*
- Special assessment studies include one for Stream Segment 2a (zinc loads) for CCWF and for an update of Cd concentrations and exceedances (UCCWA). Highlights are provided herein.
- The most recent 2018 UCC TMs Addendum for CCWF includes a subwatershed WQ assessment of Lion & North Empire Creeks.
- A preliminary evaluation of TMs-concentration time trends indicates patterns that differ from an earlier study using data for the Snake River, alluding to climate-change impacts (work in progress).

# The “Maturing” of Water-Quality Monitoring Networks

*Sources: CSU WQ Monitoring Short Course; Integrated Watershed Approaches – The 3M Concept*



## Integrated Watershed Approaches

Block Course, Friedrich-Schiller-Universität Jena, Institut  
for Geography, Department of Geoinformatics,  
Hydrology and Modeling

Timothy D. Steele, Ph.D., with assistance from  
Dr. Klaus Bongartz

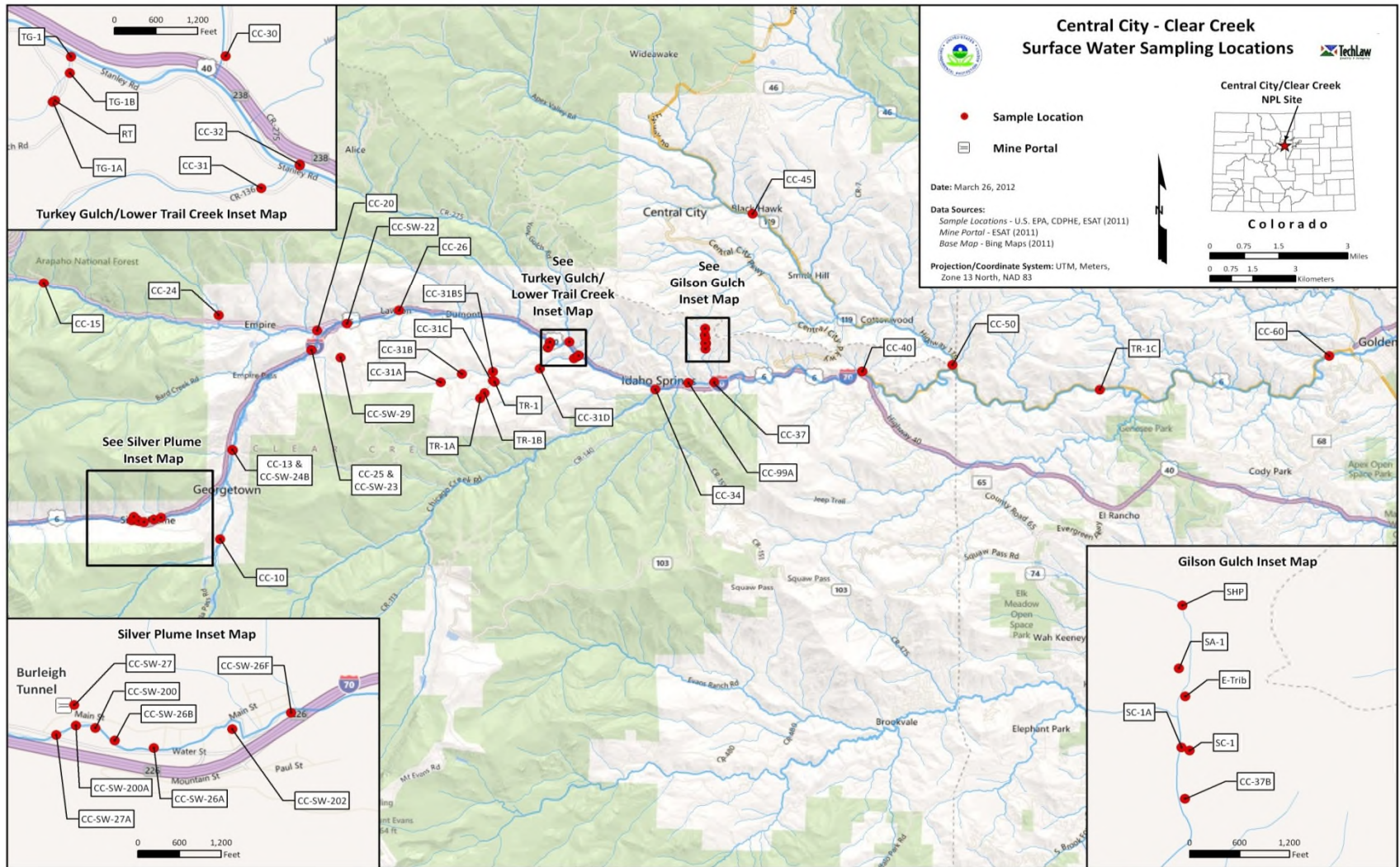
Jena, Germany 20-31 March 2006

*3M Concept*

Monitoring,  
Modeling and  
Management

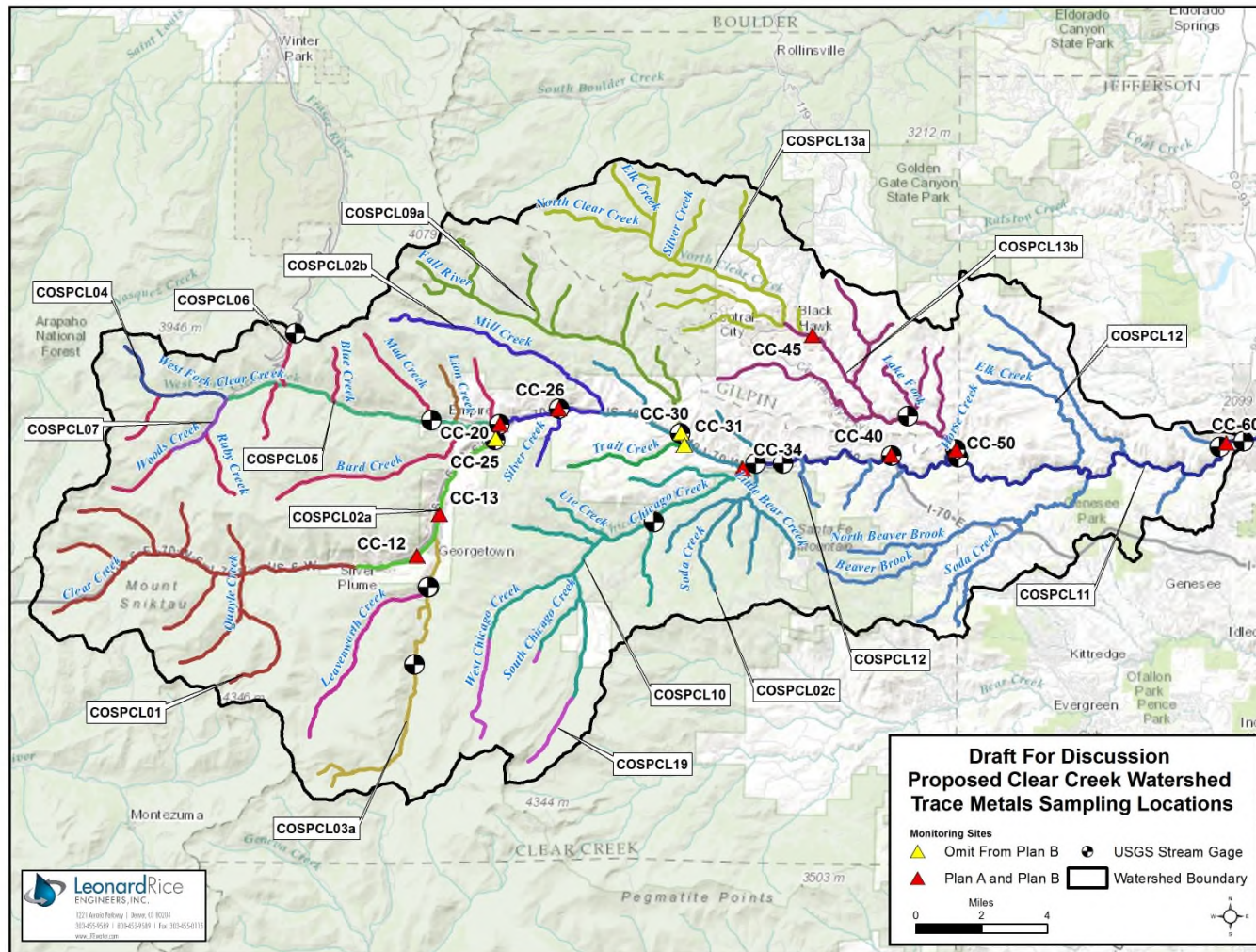


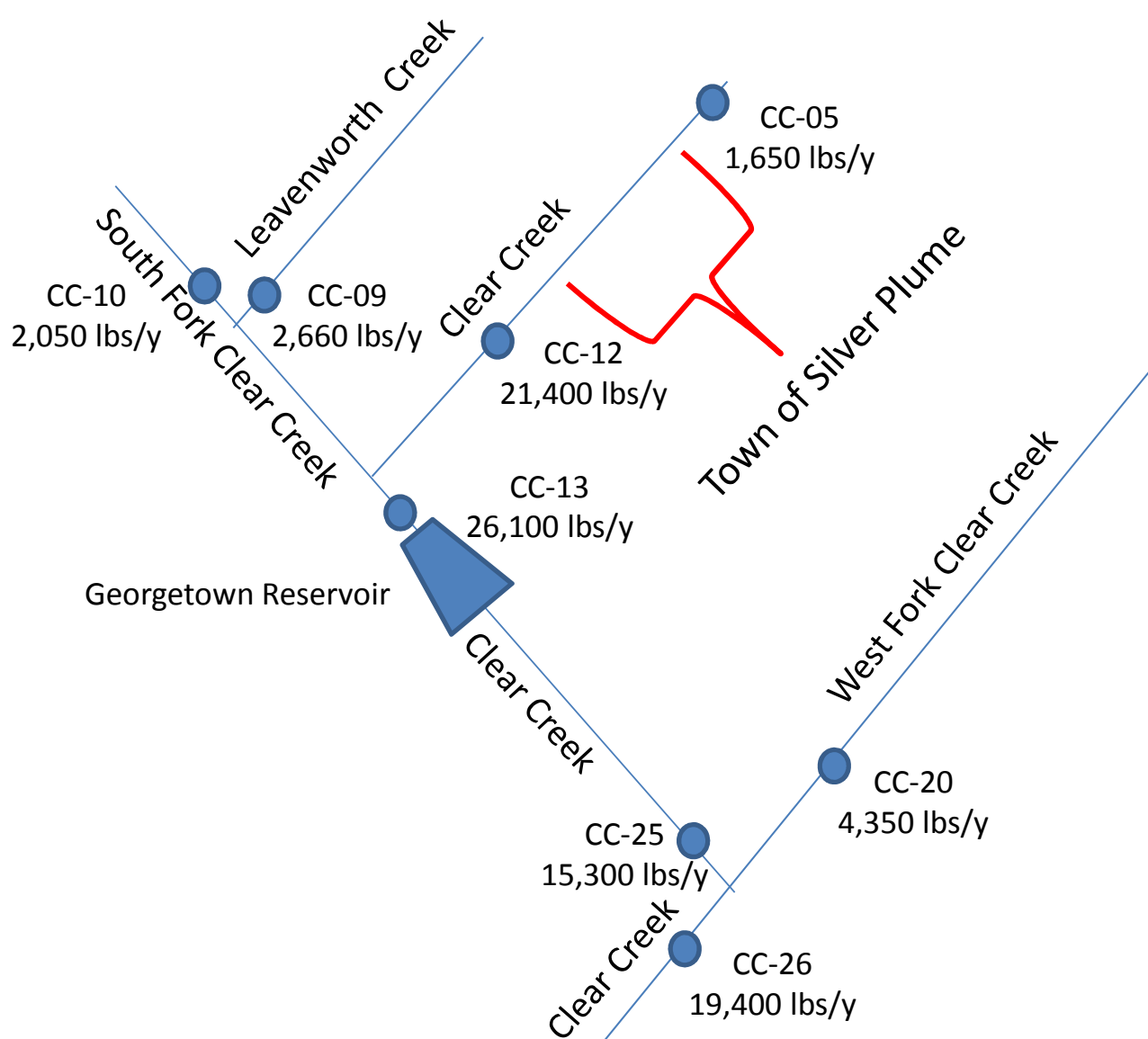
# Upper Clear Creek Watershed – Monitoring Sites





# Upper Clear Creek Watershed – Long-Term Trace-Metals Monitoring Program (showing Stream Segments)





*Note: General monitoring-site configuration; not to scale*

Upstream Part of Clear Creek Watershed,  
Estimated Annual Mean Zinc Loads at  
Key Water-Quality Monitoring Sites (Stream Segment 2a, 2010-2013 WYs)

# Summary Statistics, D-Cd (ug/L), Upper Clear Creek

## Key TMs Monitoring Sites

Source: TDS Tech Memo to UCCWA, 11/20/2014.

Stream Segment	Site	Number <sup>1</sup>	Avg	85 <sup>th</sup> %	TVS(ch)	# Exceed-ances	TVS(ac)	HRD <sup>2</sup>	HRD <sup>3</sup>
2a	CC13	38	0.83	1.32	0.34	32	2.15	75.8	64.7
2a	CC25	56	0.28	0.41	0.34	16	2.15	75.8	64.4
5	CC20	15	0.15	0.14	0.40	0	2.55	92.1	75.4
2b	CC26	44	0.26	0.36	0.34	10	2.14	75.4	72.2
9b <sup>5</sup>	CC31	84	3.08	4.12	0.36	77	2.28	81.1	102
2c <sup>5</sup>	CC34	54	0.41	0.65	0.37	27	2.34	83.5	69.6
11	CC40	87	0.55	0.86	0.41	43	2.67	96.9	73.2
13b	CC50	60	2.03	3.24	4.7 <sup>4</sup>	1	[3.40] <sup>4</sup>	128	150
11	CC60	53	0.48	0.71	0.41	28	2.67	96.9	80.2

**Footnotes:** 1 Number of detectible concentrations, 2007-2014 (D-Cd < 0.2 ug/L).

2 Source: CDPHE-WQCD (2009), HRD (mg/L) for multiple sites in stream segment (SS). It is recommended that the table value standards (TVSs) calculated in 2009 for the WQCC RMH deliberations be updated.

3 Source: TMs data file, period of record, 2/1994-8/2014; except CC13>2/10; CC26 >4/98; CC31 >2/05. 4 Temporary modification, expiring 7/1/2015; TVS (ch) = 0.51 ug/L for SS 13b (with 50 exceedances).

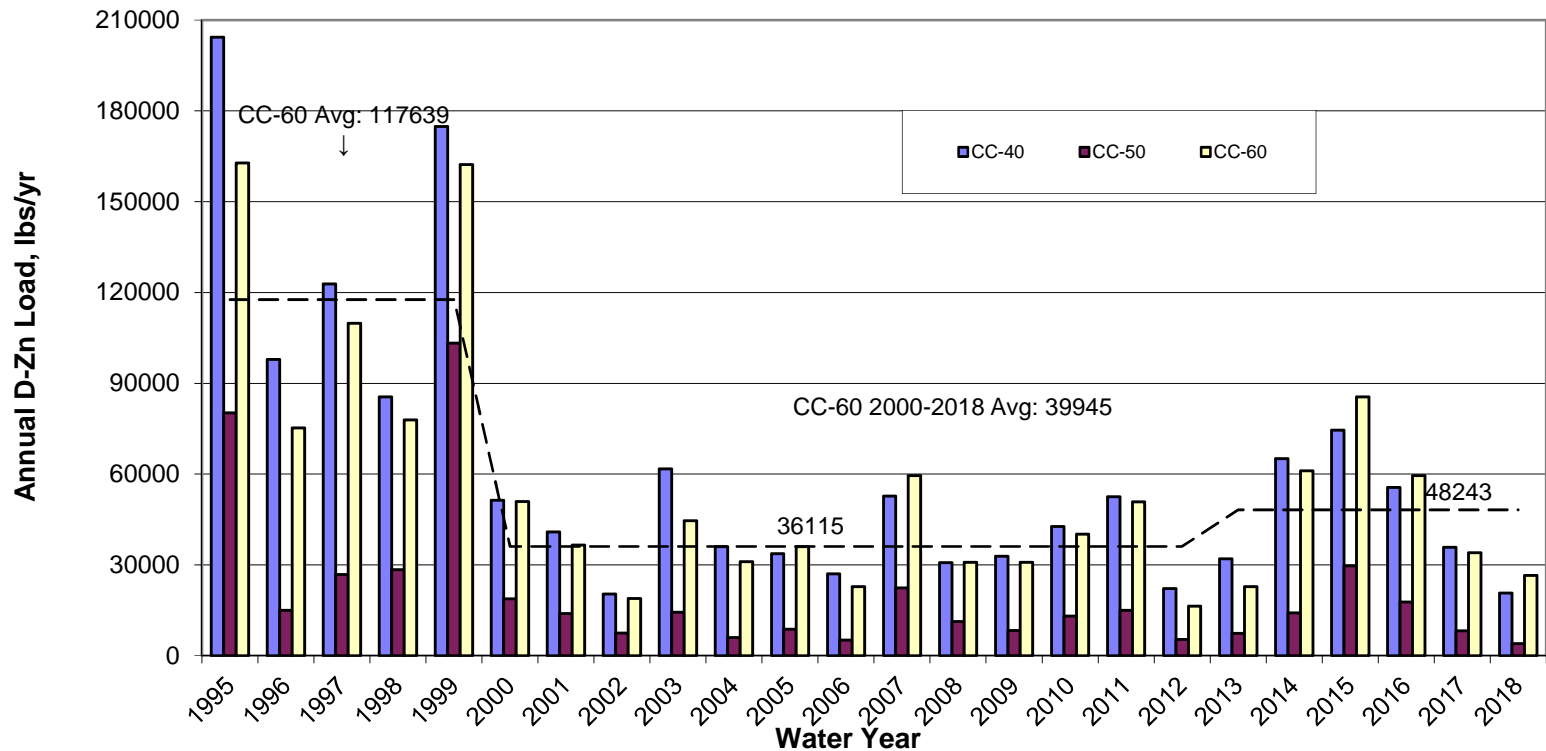
5 Sites CC31 Trail Creek at mouth & CC34 Clear Creek above Chicago Creek are added for comparison.



# Comparison of Annual Downstream UCC Watershed Zinc Loads, 1995-2014 (CC @ Kermitts vs. NFCC vs. CC near Golden)

*Source: TDS Consulting (2018), 2018 TMs Addendum, draft report to CCWF*

## A. Lower Stream Sites



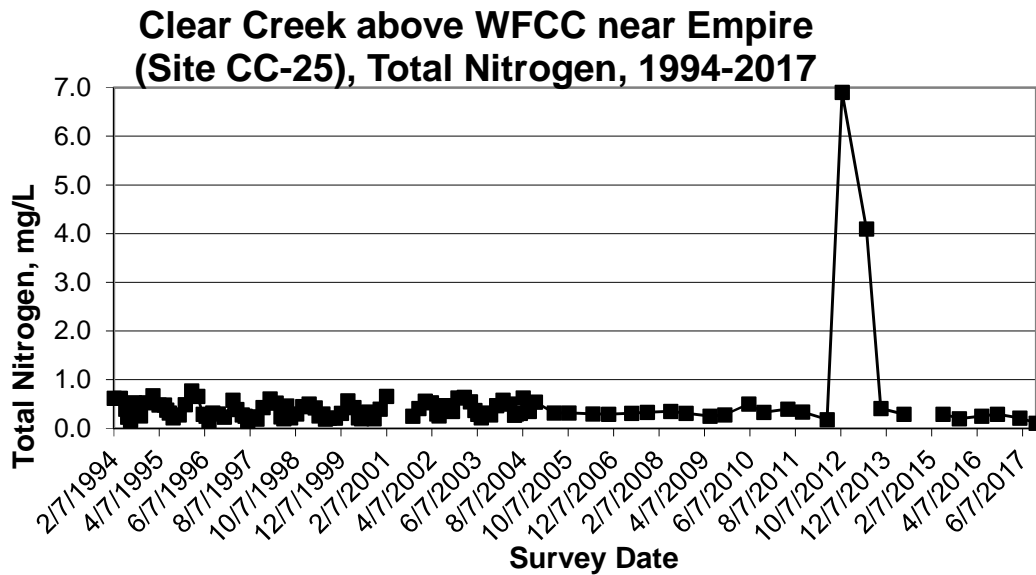


# Upper Clear Creek Watershed

## Stream Standards TVS/Temp Mod Compliance Evaluation

*TDS Tech Memo to UCCWA, June 6, 2014*

Stream Segment	Hardness mg/L, (N=)	Dissolved Trace Metal	# data values	85 %ile	TVS (ac), ug/L	TVS (ch), ug/L	Temp Mod, ug/L
2a	74 (114)	Cadmium	100	1.18	1.3	0.34	1.54 (ch)
2a	74 (114)	Zinc	130	258	270	236	586 (ac)/353 (ch)
2c	73 (137)	Copper	81	7.93	10	6.8	11.4 (ch)
9a	29 (77)	Copper	54	7.76	4.2	3.1	9.6 (ch)
11	96 (202)	Cadmium	150	0.838	2.6	0.31	1.42 (ch)



## Examples Giving the Importance of Continued Water-Quality Monitoring



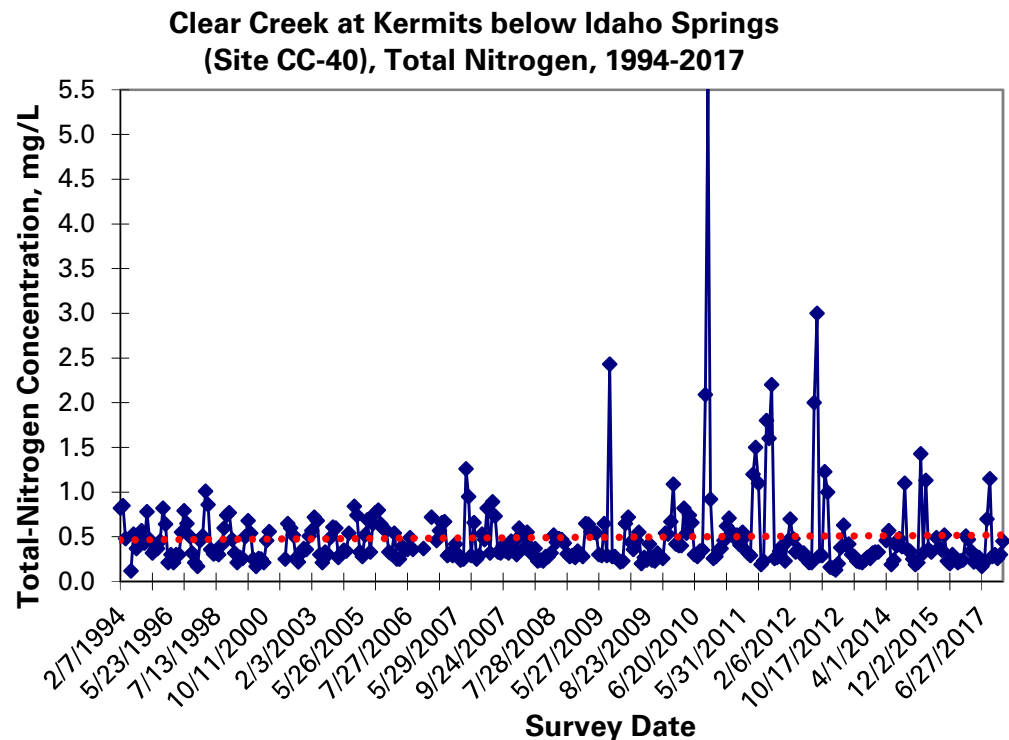
**UPPER CLEAR CREEK  
WATERSHED ASSOCIATION**



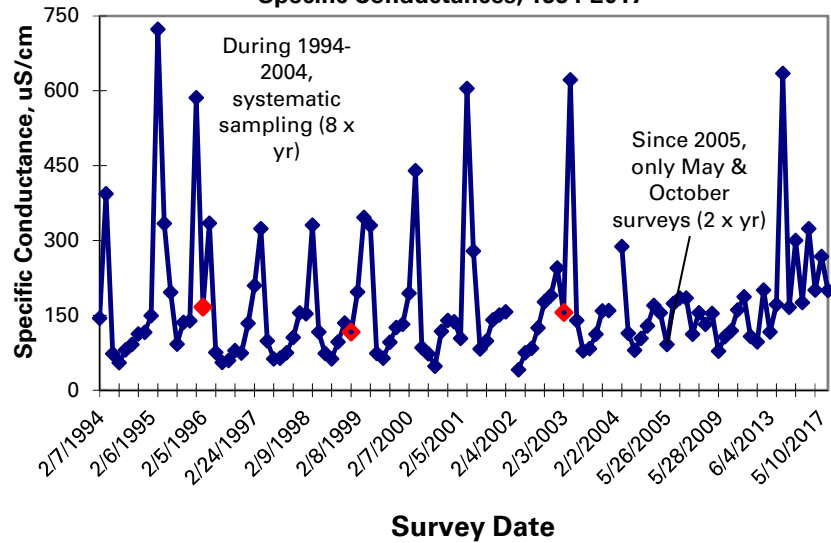
Site CC-25, what happened during two recent sampling surveys? “WWTP Hiccup?”



Site CC-40, indicating the effect of comingling ambient samples and automatic-sampler composite (since 2006, with no increase in T-N concentration). “WWTP/forest impacts?”

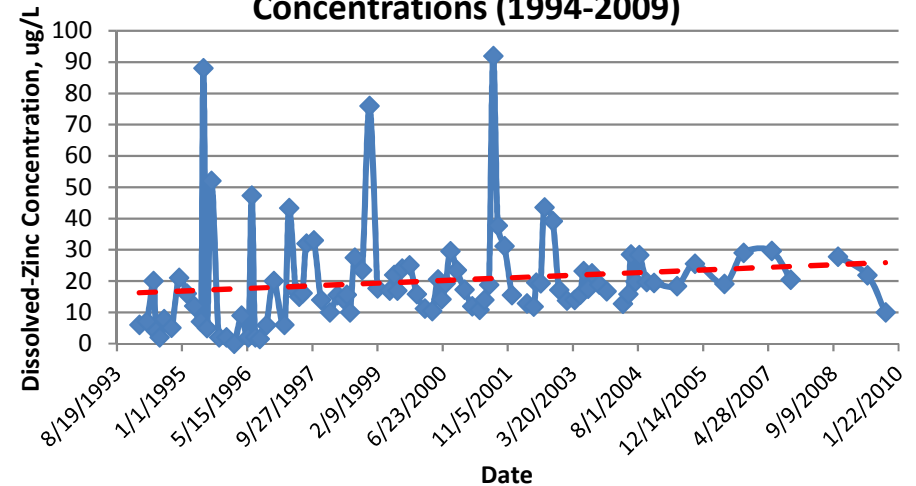


**Clear Creek at Bakerville (Site CC-05),  
Specific Conductances, 1994-2017**



**Now to go back to the beginning.....**

**Clear Creek near Bakerville (CC-05), Zinc Concentrations (1994-2009)**

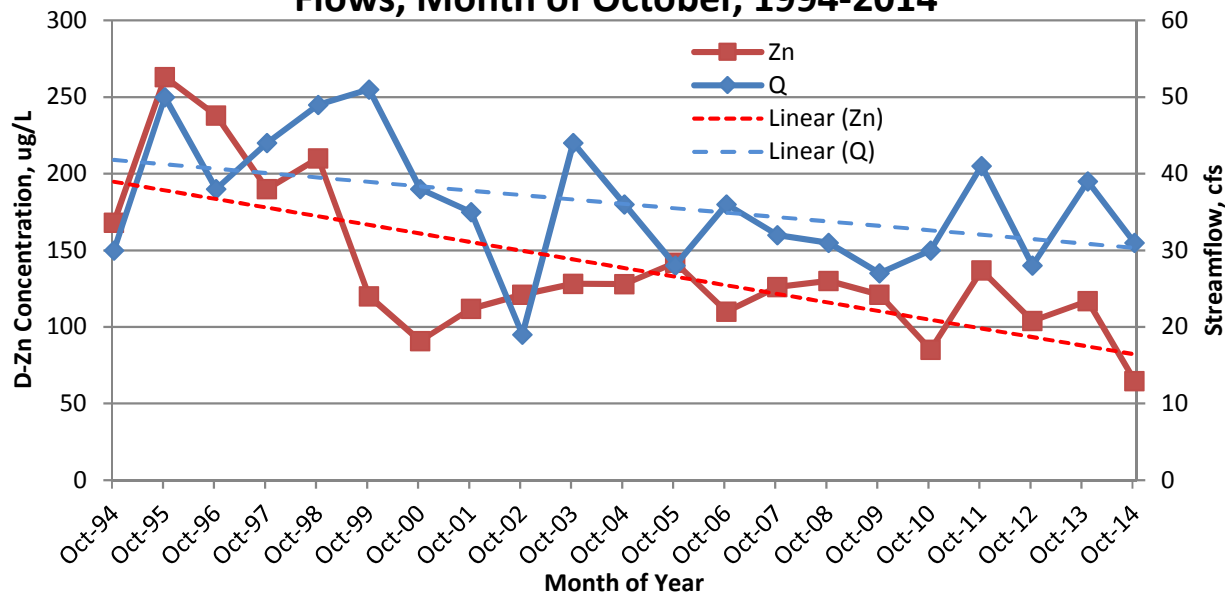


- Seasonal characterization (including extreme values) is “lost” by reducing frequency of sampling/analyses to twice per year (such as high/low flow).
- Time trends may occur even higher up in the watershed (near headwaters); thus, supporting the continuation of WQ monitoring data.
- Further assessment of the available data (all sources) is warranted!



# Seasonal time trends due to climate change?

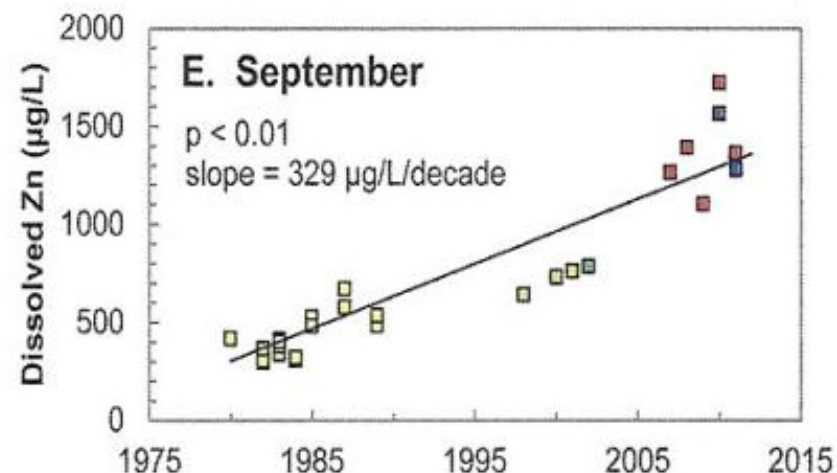
**Clear Creek ab WFCC (CC-25), D-Zn Concentrations and Flows, Month of October, 1994-2014**



Clear Creek (to the left) Indicates decreasing zinc concentrations; whereas, the Snake River (below; west “over the Continental Divide”) indicates increases in zinc concentrations.

*Snake River Watershed ----*

Sources: Steele et al. 2010; 2015); Todd et al. (2012; 2013) & UCC & Snake River watersheds' databases.

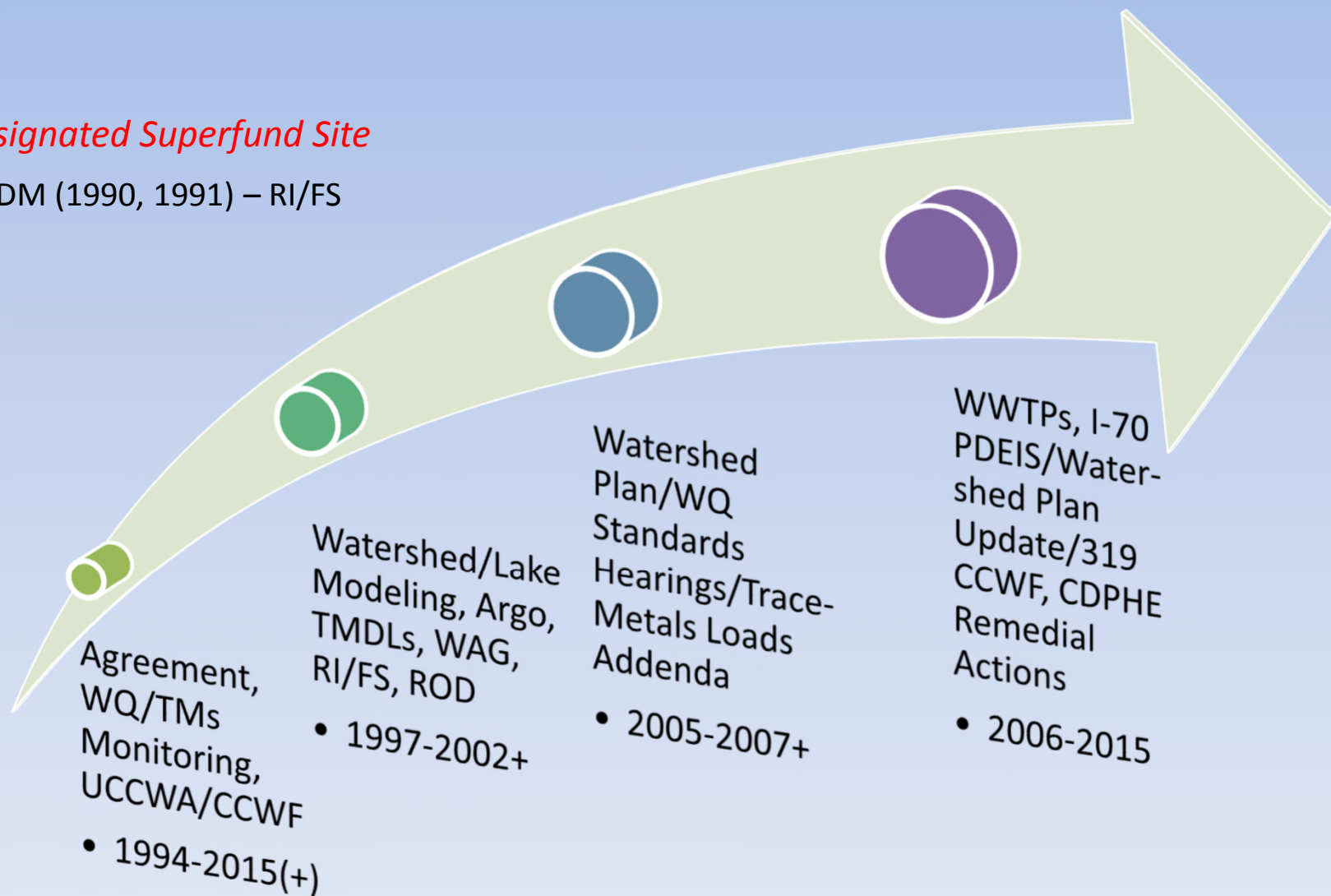




# More than Two Decades of Investigations for Evaluating Conditions and Changes, Upper Clear Creek Watershed

## *Designated Superfund Site*

CDM (1990, 1991) – RI/FS



# Parties to the Clear Creek Watershed Management Agreement

## MUNICIPALITIES

Westminster  
Thornton  
Northglenn  
Idaho Springs  
Georgetown  
Empire  
Black Hawk  
Central City  
Arvada  
Golden

## COUNTIES/GOVERNMENT

Jefferson County  
Clear Creek County  
Gilpin County  
St. Mary's Glacier W&S  
Black Hawk/Central City W&S  
Central Clear Creek W&S  
Colorado Dept. of Transportation  
Jefferson Center Metro District

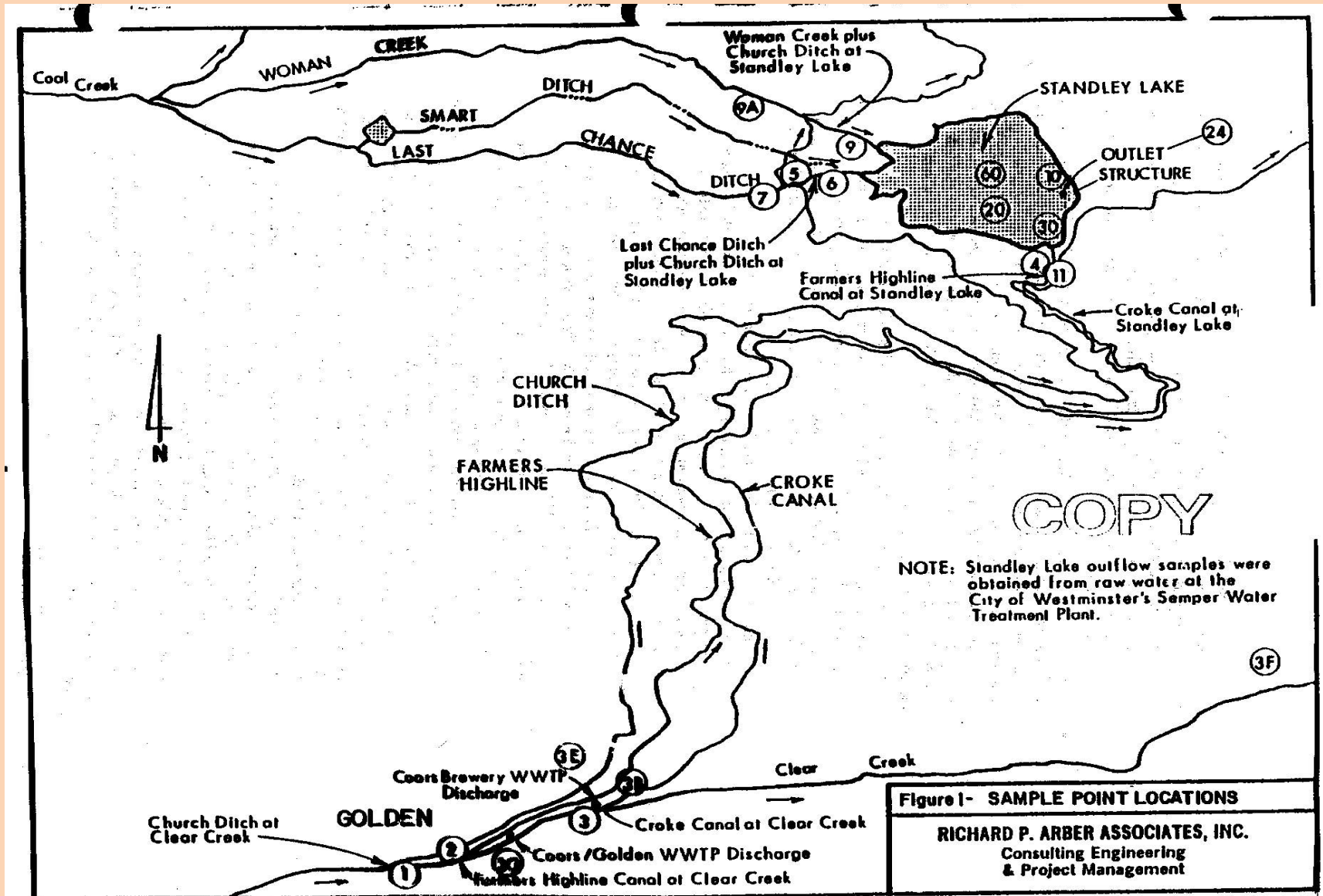
## INDUSTRY/IRRIGATION

Phelps Dodge  
(Cyprus/Amax)  
Clear Creek Ski Corp.  
Farmers' High Line  
FRICO  
Church Ditch

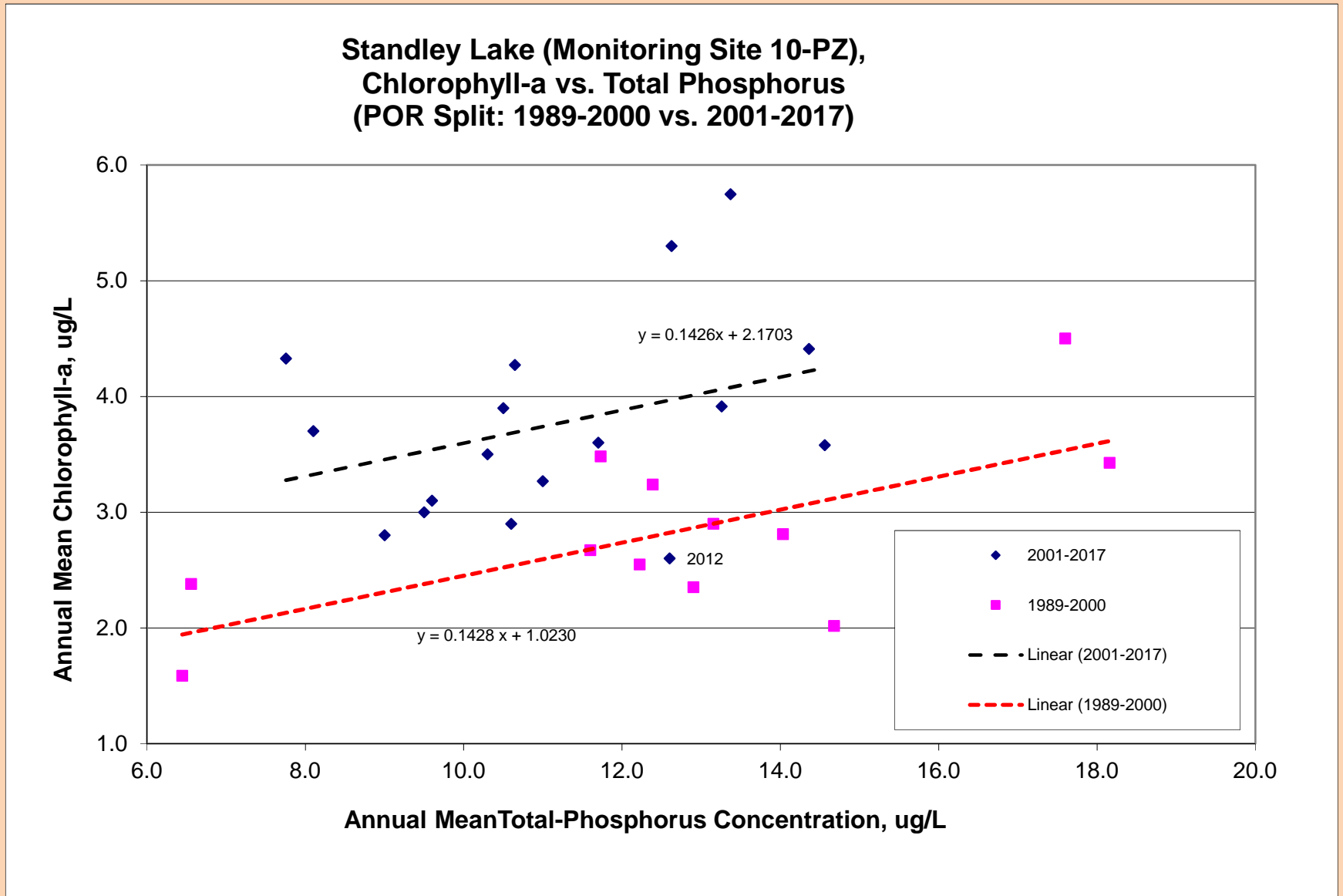


**UPPER CLEAR CREEK  
WATERSHED ASSOCIATION**

# Upper Clear Creek Watershed with Canal-Diversion Flows into Standley Lake



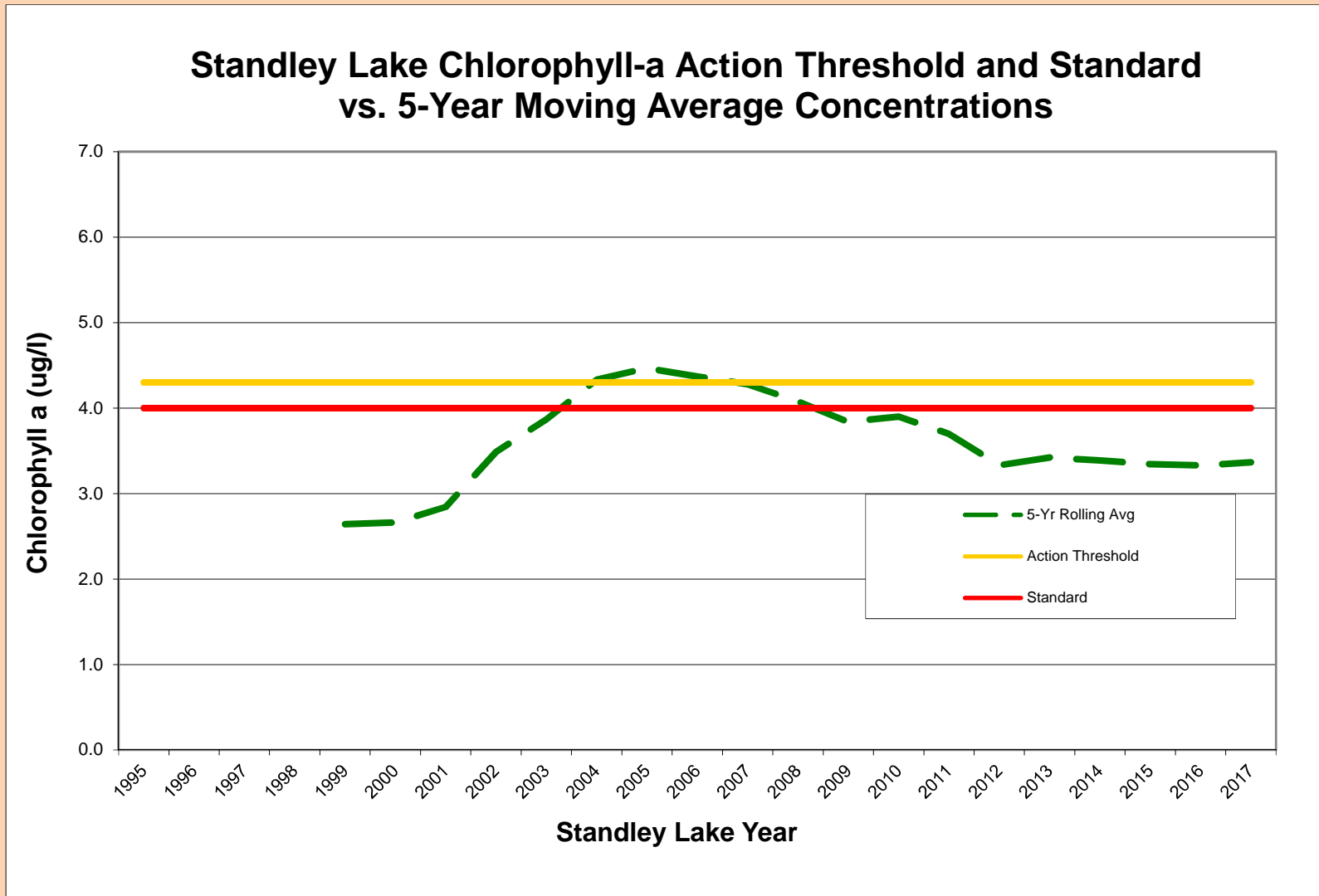
# Shift in Chlorophyll-a vs. Total-Phosphorus Pattern





# Downstream Standley Lake Chlorophyll-a Rolling-Average Concentrations vs. Action Threshold/Standard

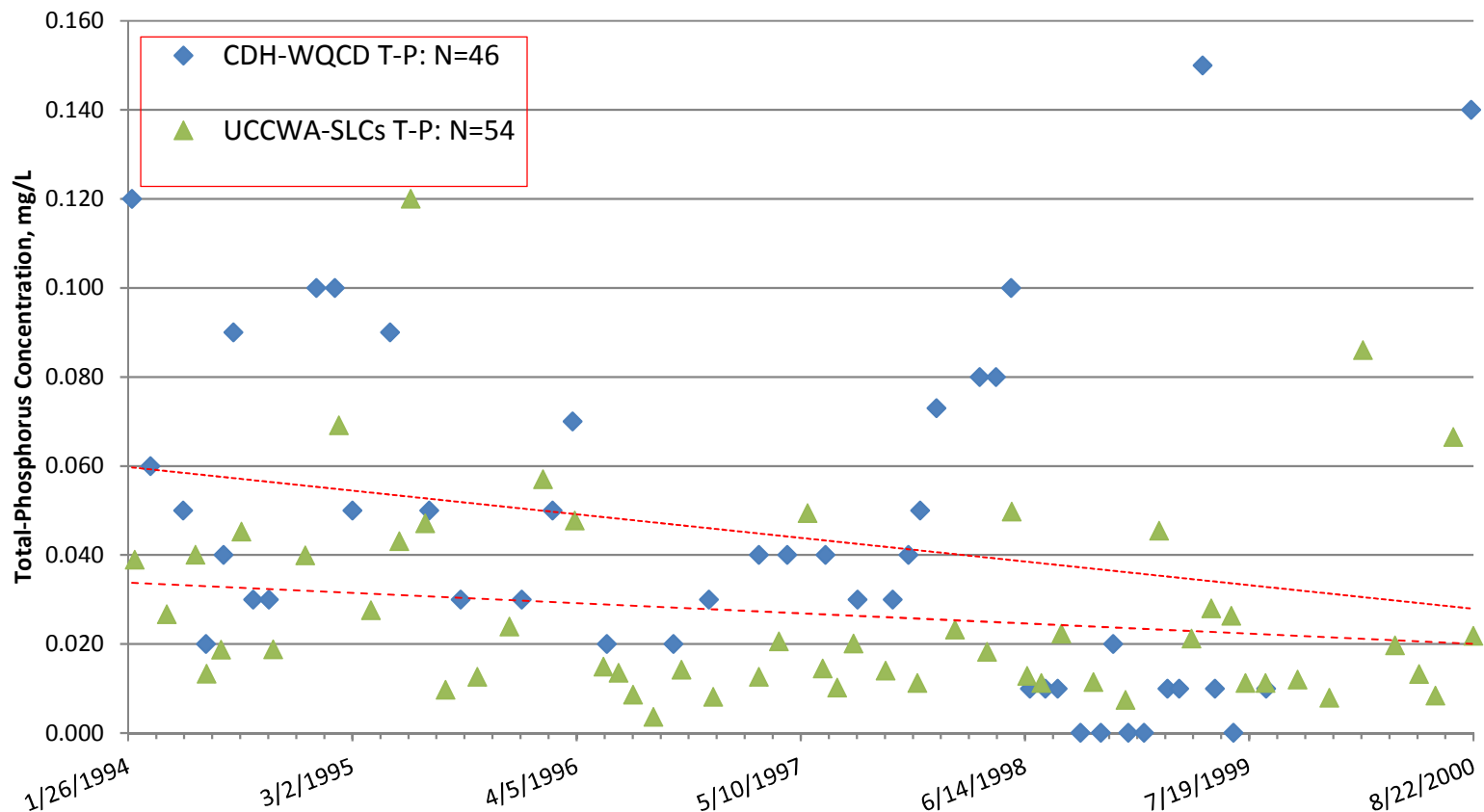
*Source of data: Standley Lake Cities (Westminster, Northglenn, Thornton)*



# Importance of Data-Source Comparisons

*UCCWA-SLCs POR Average T- P is 40 percent lower than for CDH-WQCD (0.027 mg/L vs. 0.45 mg/L)*

**Figure 3 -- Clear Creek near Golden, Total-Phosphorus Concentrations, February 1994-August 2000, WQCD vs. UCCWA-SLCs Data Comparison**

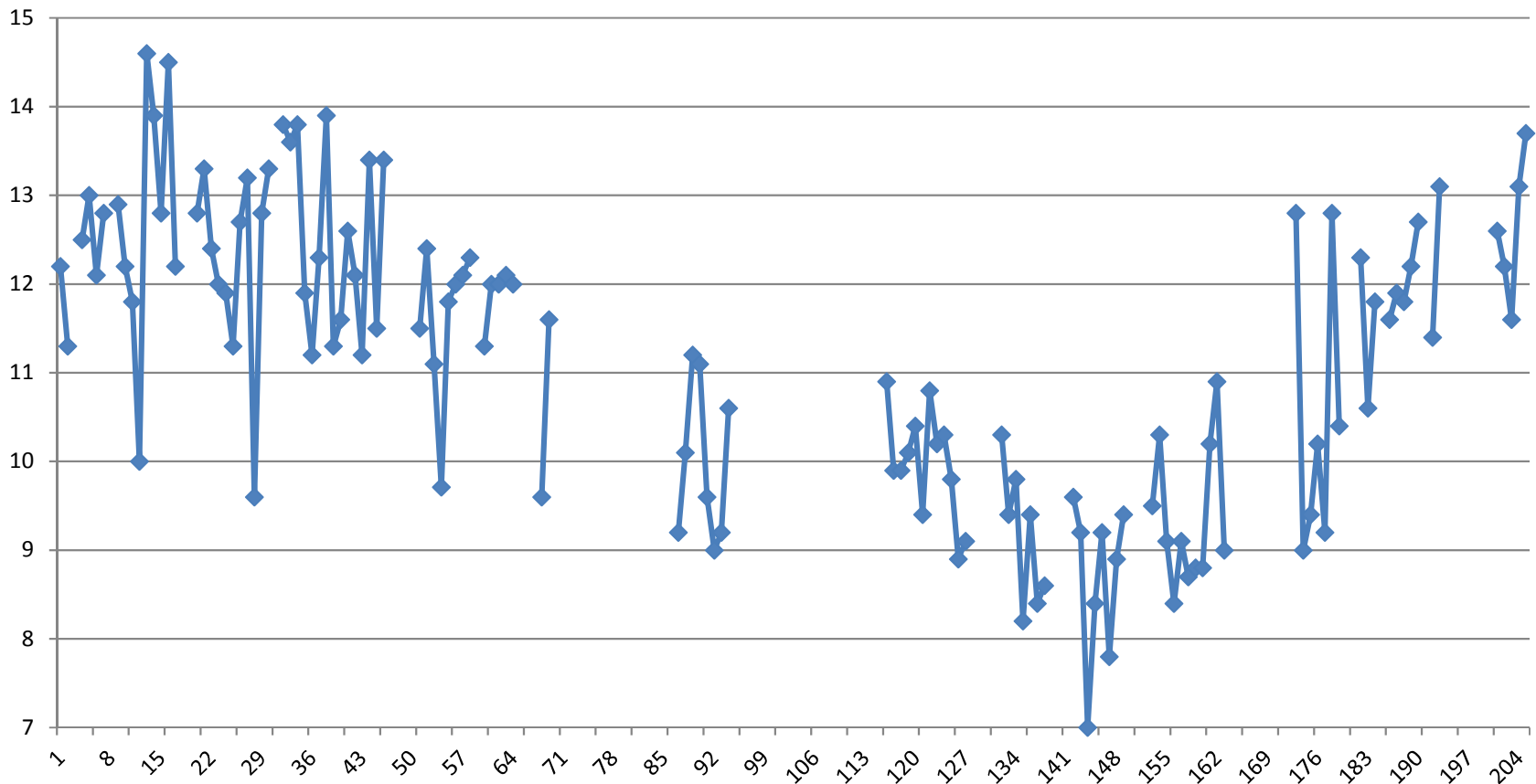


# Seasonal DO Characterization of Clear Creek

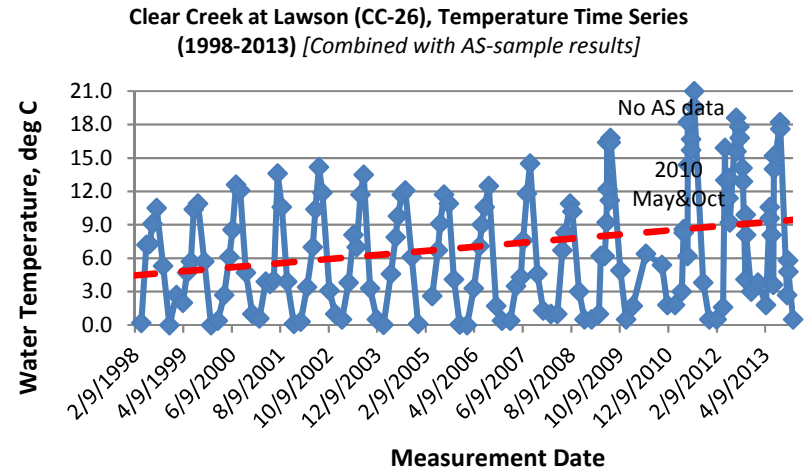
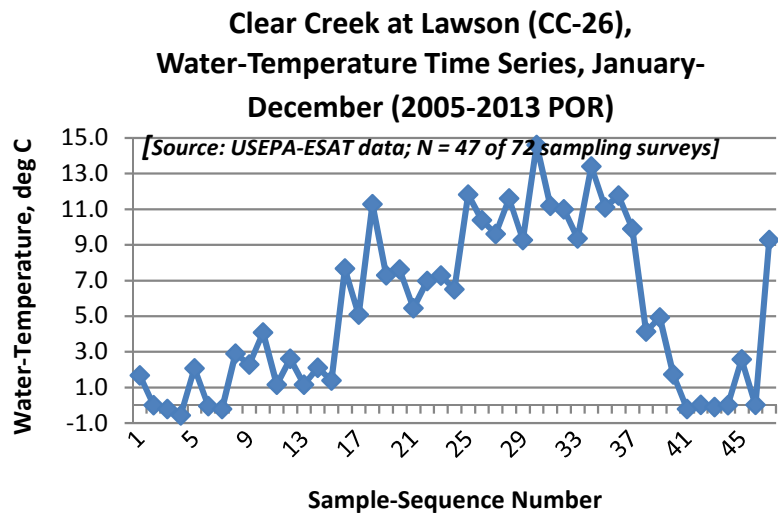
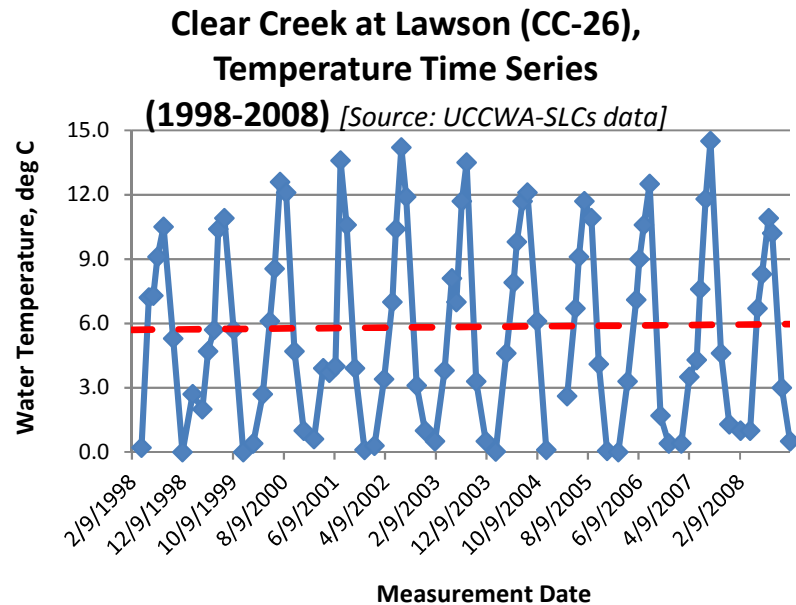
## 26 years of field measurements during sampling surveys

Clear Creek near Golden (WQCD Site 00035), Dissolved-Oxygen Concentrations (mg/L), Seasonal Pattern, 1974-1999

*(partial data set, omit 2 anomalous values)*



# Stream Temperature – An “Emerging” Water-Quality Variable of Concern



## Comments:

1. More data may not always provide “better” information (characterization/statistics).
2. Time trends are period-of-record dependent.
3. Comparisons with different data sources are useful.
4. Seasonal characterization can be “captured” via a simple harmonic function (next).



# Stream Temperatures Seasonal Characterization

[Ward (1963); Collins (1969); Steele (1974; 1985); Shampine (1977); Wentz and Steele (1976); Clement (1978)]

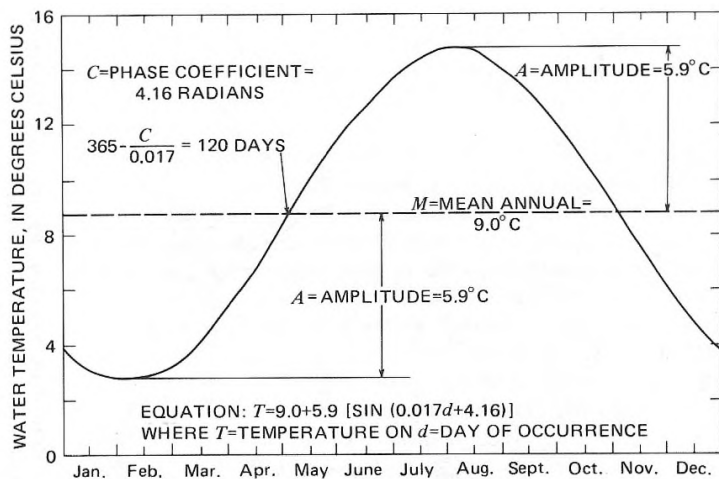


FIGURE 2.—Typical harmonic-fitted temperature graph showing mean stream-temperature curve, for station 12-0830, Mineral Creek near Mineral.

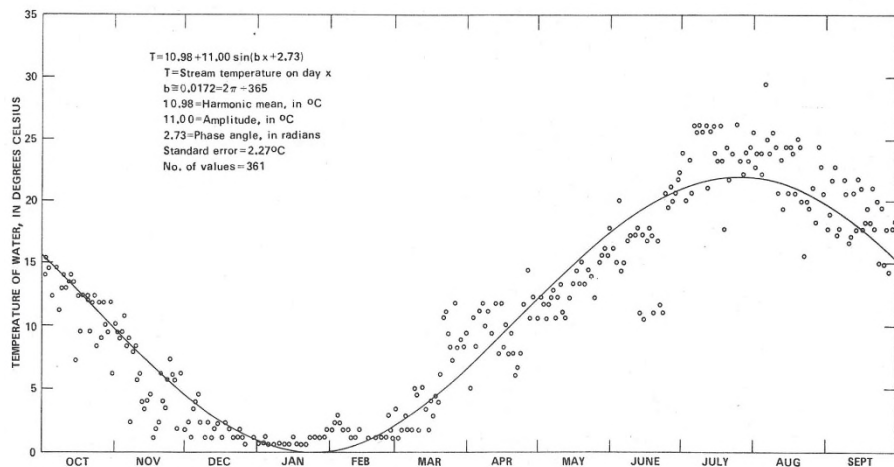
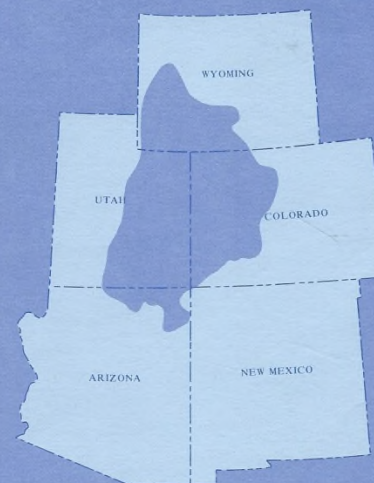


Figure 2a.—Seasonal temperature pattern, Yampa River near Maybell, Colo., 1963 water year.

## HARMONIC ANALYSES OF STREAM TEMPERATURES IN THE UPPER COLORADO RIVER BASIN



U.S. GEOLOGICAL SURVEY  
Water-Resources Investigations Report 84-4290



# Integrated Watershed Approaches

Block Course, Friedrich-Schiller-Universität Jena, Institut  
for Geography, Department of Geoinformatics,  
Hydrology and Modeling

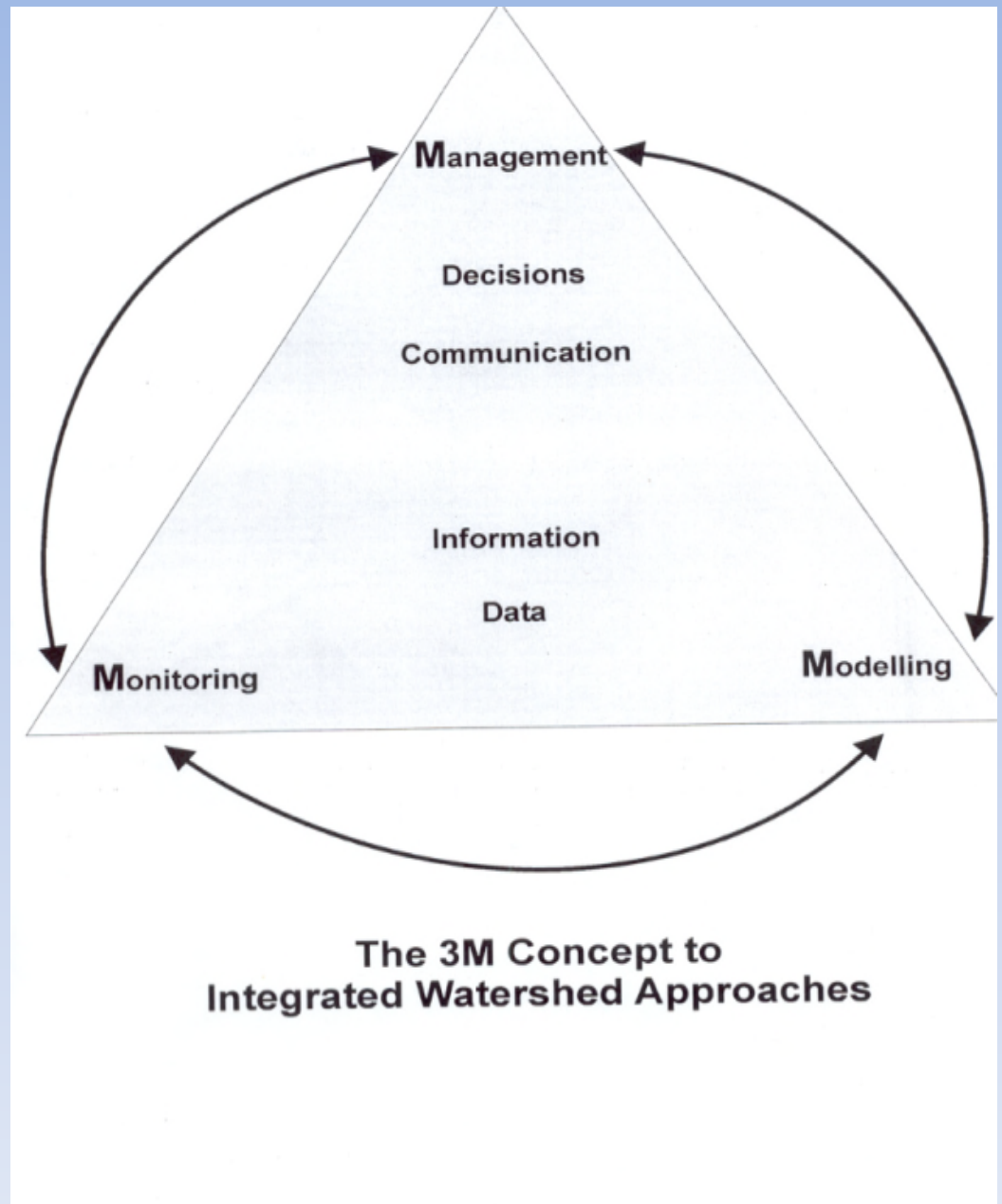
Timothy D. Steele, Ph.D., with assistance from  
Dr. Klaus Bongartz.

Jena, Germany

20-31 March 2006

*3M Concept*

Monitoring,  
Modeling, and  
Management.



## UPPER CLEAR CREEK WATERSHED INTEGRATED HYDROLOGIC & WATER-QUALITY MONITORING – Conceptual-Design Guidelines



Source: SCS PP presentation, 2008.

Draft Prepared by

Timothy D. Steele, with Assistance from Max Dodson

On behalf of

Clear Creek Watershed Foundation and

Upper Clear Creek Watershed Association

TDS Project No. 0411-11X

April 11, 2012 (version R4)

# Tabulation of UCC WQ Model Applications

- 1994 – CDM water-management study *(CDM/RBD)*
- 1994-1998 QUAL2E studies *(DRCOG, HIS Geotrans; TDS Consulting)*
- 1995-1999 -- Meta4-WASP4 *(Al Medine, USEPA-Cincinnati)*
- 2002+ -- TMDL assessments *(CDPHE-WQCD)*
- 2003 – TPLoad *(USEPA BASINS tool set, Clear Creek Consultants)*
- 2001-2006 – WARMF (watershed & lake) *(SLCs)*
- “Black-Box” Models:
  - Trace-metals loads assessment (2000-2014 & 2018) – annual addenda
  - Harmonic analysis of stream (water) temperatures



# Acknowledgments

## *TDS' Clear Creek watershed involvement*



- U.S. Environmental Protection Agency
- U.S. Geological Survey, Water Resources Division
- Colorado Department of Environmental Health & Environment
  - Hazardous Materials & Waste Division
  - Water Quality Control Division
- Clear Creek County
- Adams County
- Town of Georgetown
- City of Black Hawk
- City of Golden
- Standley Lake Cities (SLCs)
  - City of Westminster
- Consultants
  - Balloffet and Associates, Inc. [Town of Empire]
  - Leonard Rice Water Engineers [Black Hawk]
  - Clear Creek Consultants [Hoop Creek studies]
- Climax Molybdenum Company (previously Cyprus Amax; now a Freeport McMoran company)



# Questions



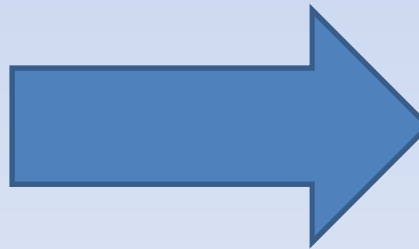
**FINAL REPORT  
UPPER CLEAR CREEK BASIN/STANDLEY LAKE  
WATER-QUALITY ASSESSMENT**

Prepared for  
Upper Clear Creek Basin Association  
c/o City of Idaho Springs  
1711 Miner Street, Box 907  
Idaho Springs, CO 80452

Prepared by  
Advanced Sciences, Inc.  
405 Urban Street, Suite 401  
Lakewood, CO 80228-1236

ASI Project No. 8792.01

Draft: July 8, 1993  
Revised Draft: July 22, 1993  
Final: September 22, 1993



**UPPER CLEAR CREEK WATERSHED  
TRACE-METALS DATA ASSESSMENT**

With Focus on Lion Creek-North Empire Creek Impacts on West Fork Clear Creek

*2018 Addendum and Technical Memorandum*



Prepared For:  
Clear Creek Watershed Foundation  
P.O. Box 1963  
Idaho Springs, CO 80452

On Behalf of:  
Colorado Department of Health & Environment, Water Quality Control Division, and  
U.S. Environmental Protection Agency

Prepared by:

Timothy D. Steele, Ph.D.  
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J. David Holm, P.E.  
Executive Director, CCWF  
4015 Wyandot Street  
Denver, Colorado 80211

TDS Project Number 0411-18X

February 6, 2019

Supplemental slides – not included in presentation

# Upper Clear Creek Watershed

## Stream Segment 2a – Zinc Loads Assessment

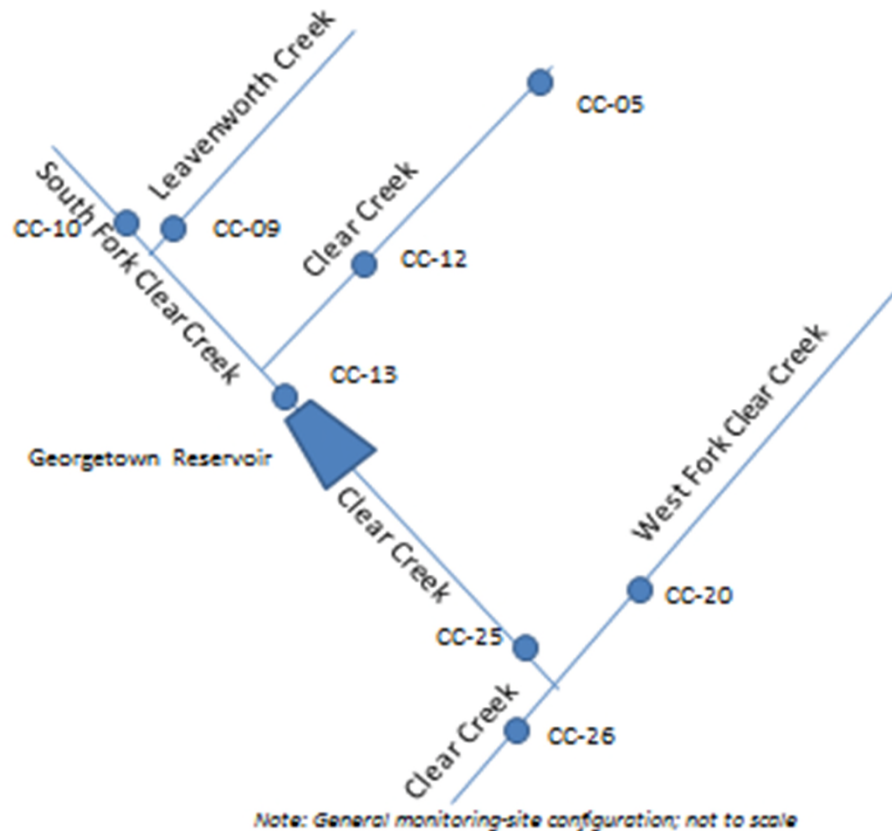


Figure 1 – Upper Part of Clear Creek Watershed,  
Key Water-Quality Monitoring Sites (Stream Segment 2a)



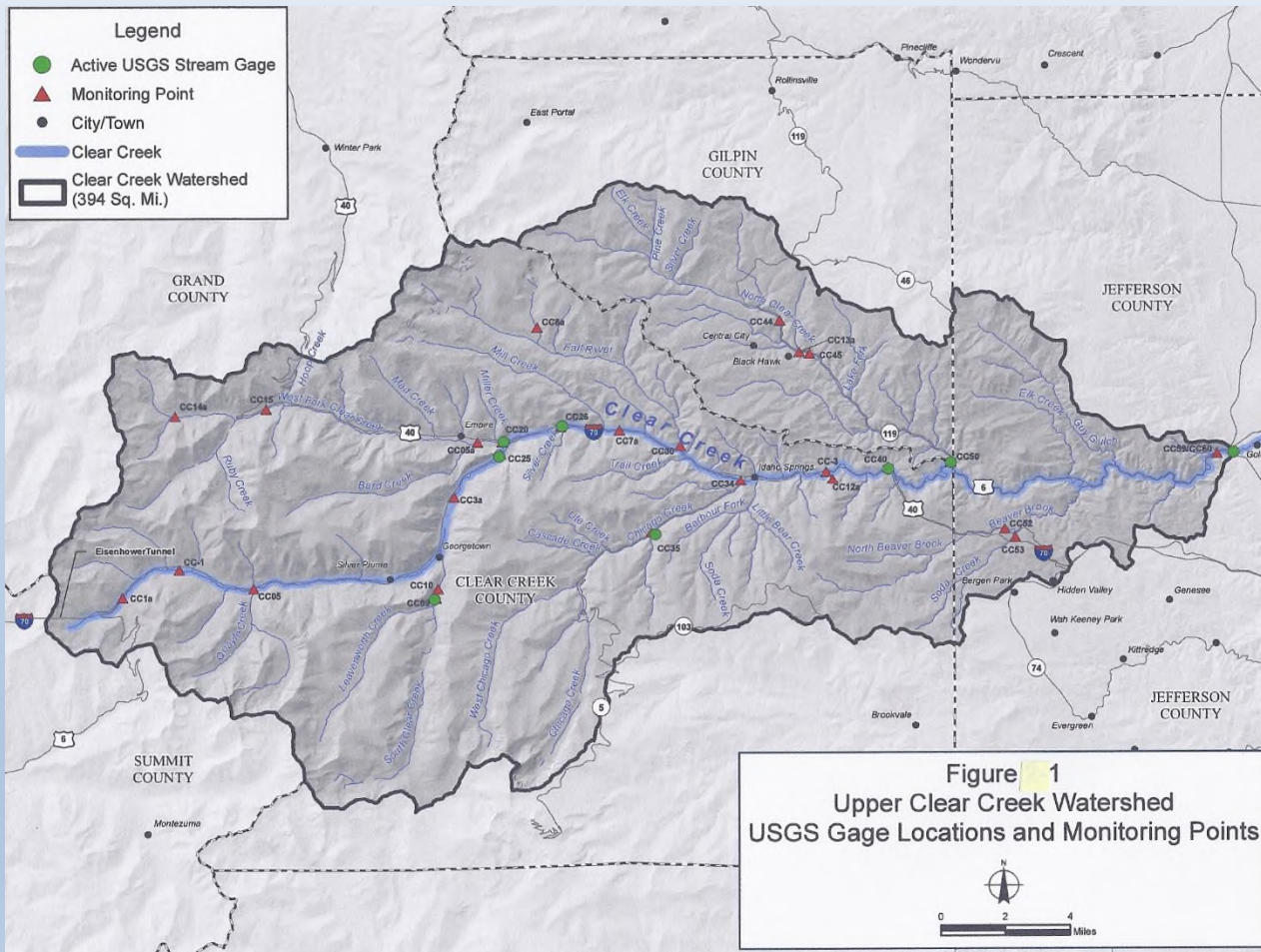
# Upper Part of Clear Creek Watershed, Comparison of Zinc Concentrations and Loads

*Source: TDS Tech Memo to CCWF, June 19, 2014.*

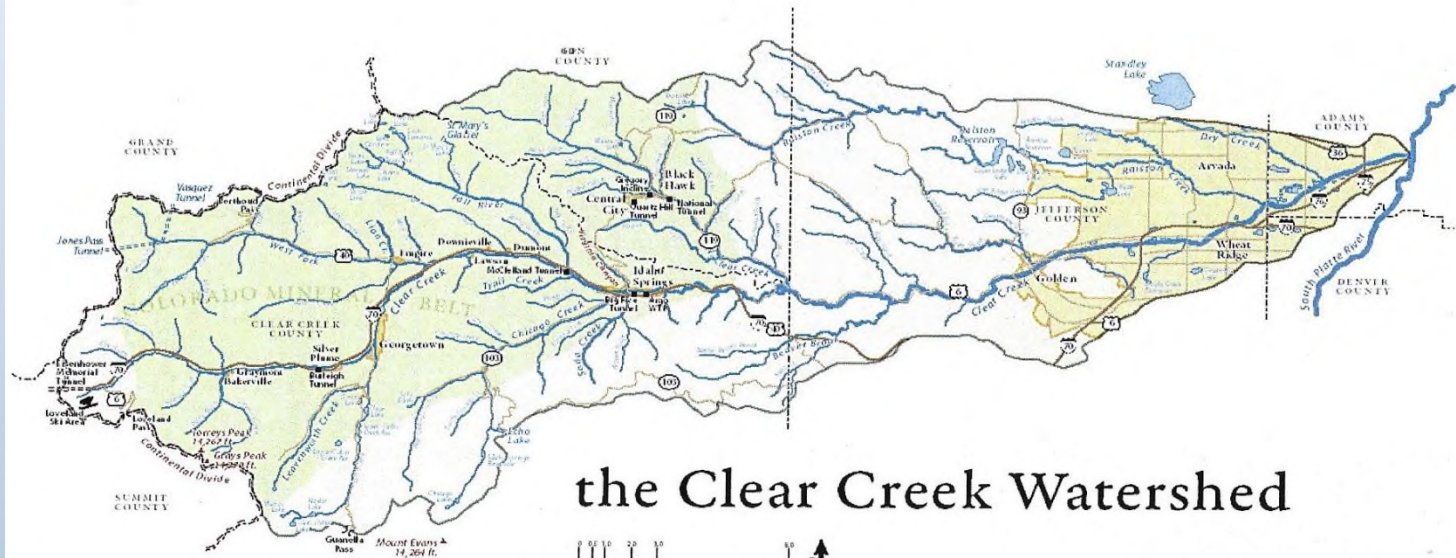
Site/Variable	CC-05	CC-12	CC-09	CC-10	CC-13	CC-25
Streamflow (Q), cfs	38.3	50.0	10.0	12.1	74.0	76.0
Q, period of record	Sampling- surveys	No data	1995-97	1995-97	1998-2013	1995-2013
Zinc concen- tration, ug/L*	20.4	276	170	73.3	234	129 [157]#
D-Zn, period of record	1994-2009	2011-2013	1999-2007	1994-2007	8/97-8/98, 2010-13	1995-2013
Zinc load, lbs/y	1,649	21,355	2657	2051	26,064	15,252

*Notes: Average zinc concentrations were obtained through interpolation of period-of-record data. However, for site CC-12, the value indicated is for an average of 16 analyses over the past three years.  
# =1994-2013 POR (19.years).*

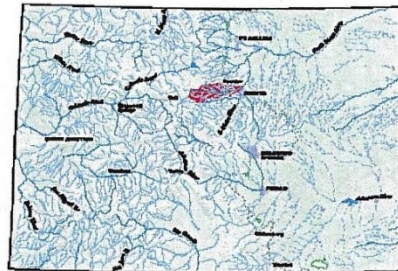
# Upper Clear Creek Watershed, Colorado





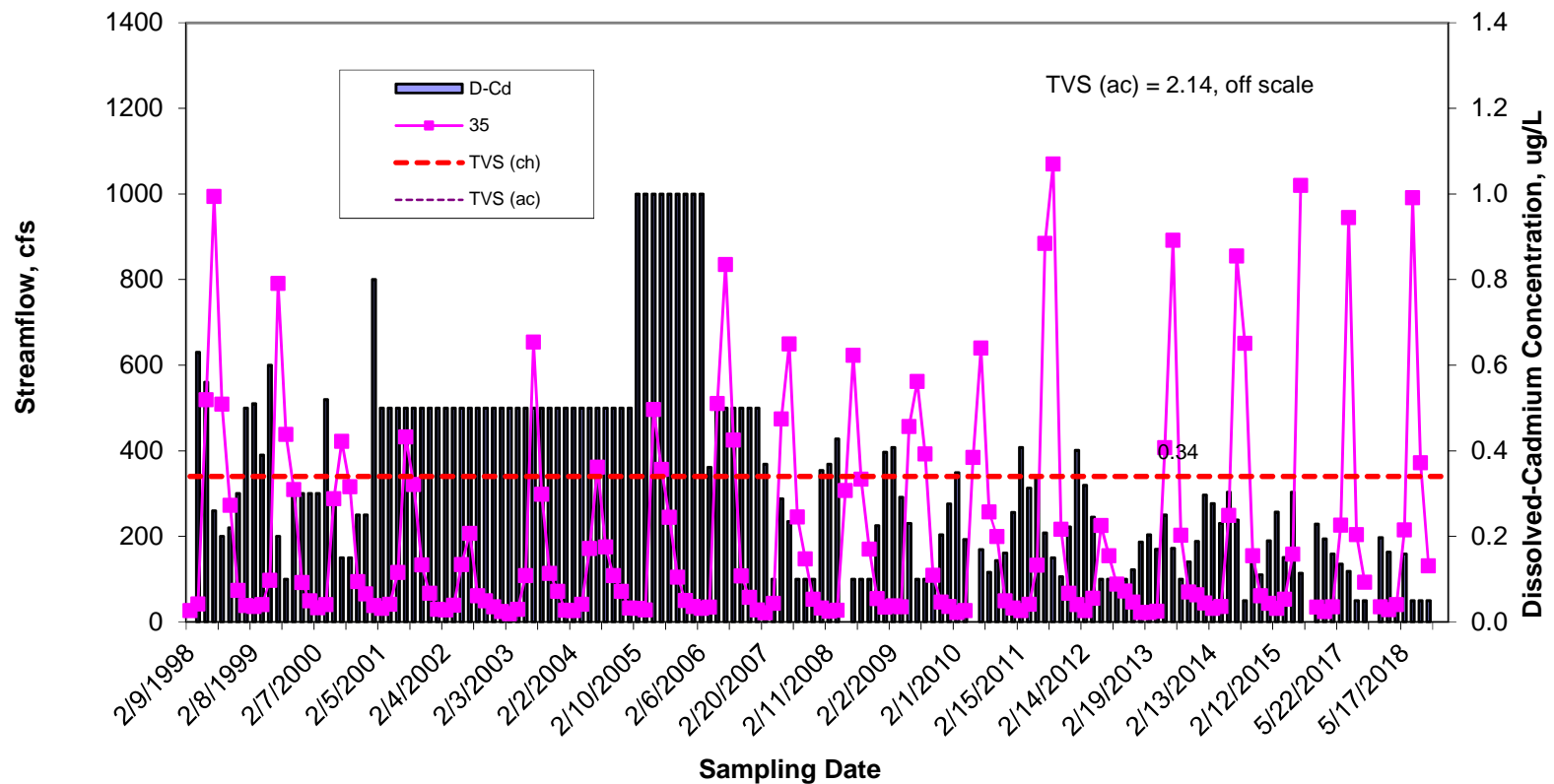


## the Clear Creek Watershed

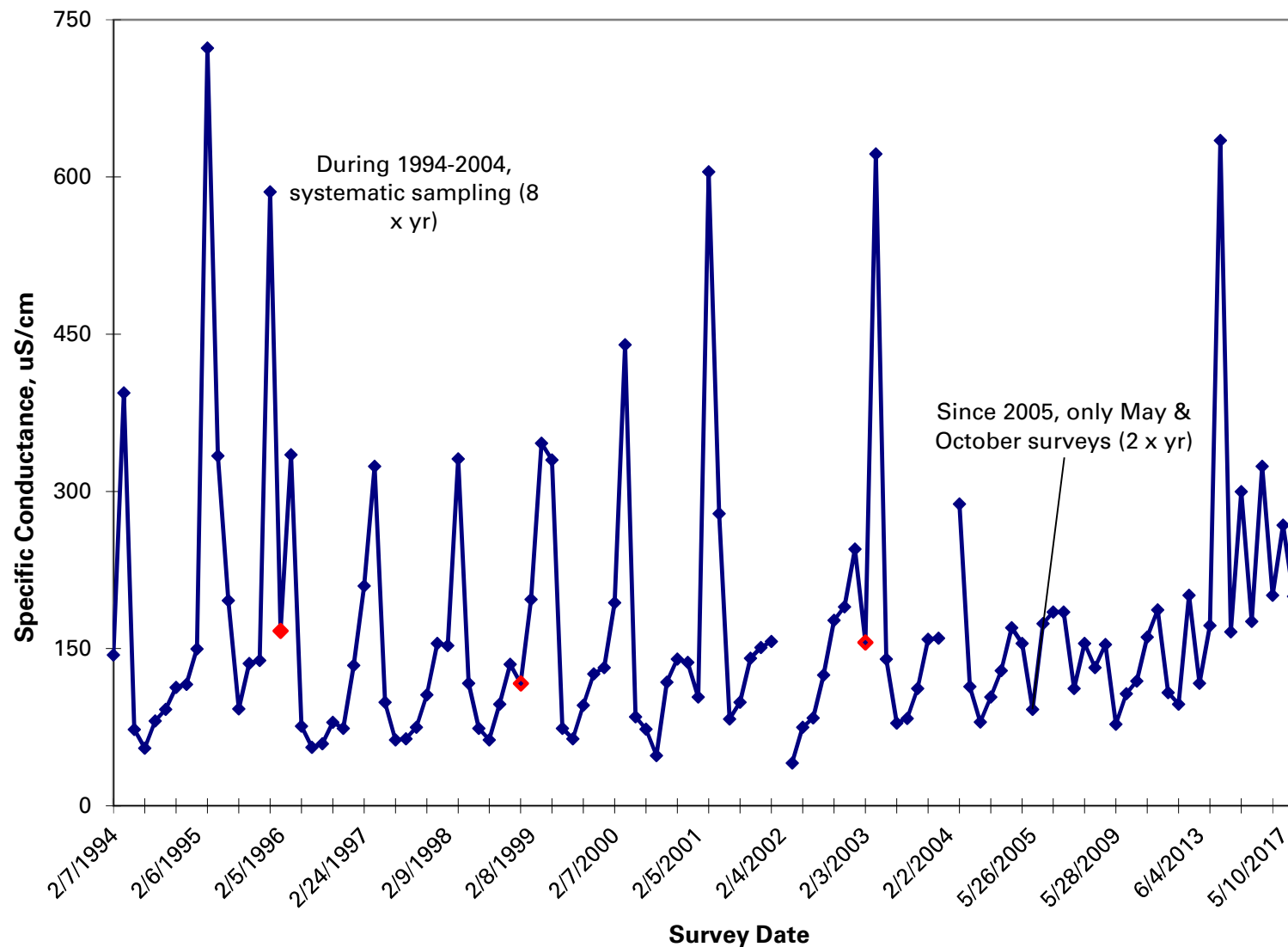


# Example – Time-Varying Minimum Detection Limits

E -- Site CC-26 D-Cd, 1998-2018



## Clear Creek at Bakerville (Site CC-05), Specific Conductances, 1994-2017



# Pitfall of Blending in Automatic-Sampler Water-Temperature Values with Ambient Field Data

**Figure 2C -- Clear Creek at Kermits below Idaho Springs  
(Site CC-40), Stream Temperatures, 1994-2017 (N = 217)**

